CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

Cosumnes River Chinook Salmon Spawner Escapement, Rearing and Emigration Surveys 1998-99 1/2/

by

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and
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August 2000

1/ This work was supported by funds provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program, as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).
2/ Stream Evaluation Program Technical Report 00-07.

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SUMMARY

The Cosumnes River chinook salmon (*Oncorhynchus tshawytscha*) resource was surveyed from November 1998 through June 1999. Data were acquired on temporal and spatial distribution of salmon spawning and on juvenile rearing and emigration. Physical data were also collected to characterize spawning and rearing habitat conditions. The primary purpose of these surveys was to identify the relationships between the various salmon life stages and existing habitat conditions and eventually identify potential management actions that could help restore the Cosumnes River salmon population to near historic levels.

Fall-run chinook salmon escapement was surveyed from 12 November 1998 through 23 December 1998. Flow during the spawning period was relatively low (100–200 cubic feet per second [cfs]). Temperature was less than 60°F beginning in early October, and ranged from 50°F to 36°F during the survey period. A total of 105 carcasses was observed. Spawner escapement within the survey reach (Meiss Road to Michigan Bar) was estimated using the Petersen mark-and-recapture model to be about 544 salmon (528 adult and 16 grilse). Aerial redd surveys conducted early in the survey period (18 November 1998) indicated that about 95% of spawning occurred within the survey reach. The total estimated escapement for the entire river was 572 salmon. However, based upon a low recovery rate of marked salmon carcasses (18%) and Law's (1994) analysis of carcass mark-and-recapture methods, we concluded that a more reasonable estimate of spawner escapement was between 250 and 350 salmon. Spawning appeared to begin in early November 1998, based upon observance of few decayed or fresh carcasses during the 12 November survey. Spawning peaked during mid-November 1998 and was completed by mid-December 1998.

Seining surveys were conducted to acquire data on temporal and spatial rearing distributions. Juvenile salmon were found rearing from Rancho Murieta upstream to Michigan Bar during March–May 1999. Recently emerged-sized salmon (<45 mm FL) were collected during March–April 1999. The largest salmon collected during March was 53 mm FL, the largest salmon collected during April was 69 mm FL, and the largest salmon collected during May was 77 mm FL. No salmon were collected during June.

Emigration was monitored using a 5-ft diameter rotary screw trap located downstream of the spawning reach (near RM 23). Trapping began late in the season, 7 April 1999. The highest catch rate occurred during the first week of trapping. No emigrating salmon were collected after the first week of June 1999. Recently emerged-sized salmon were captured through mid-May; large, smolt-sized fish (>70 mm FL) were collected every week from 26 April–4 June 1999.

Spawning migration appeared to be delayed by low fall flows. Although temperatures were well below 60°F during mid October, flow was low, less than 100 cfs at Michigan Bar. Spawning did not appear to begin until flow exceeded 200 cfs at Michigan Bar. Rearing and emigration appeared directly related to temperature rather than flow. Flow was relatively high (>200 cfs) during early June when temperatures exceeded 65°F and salmon catches declined to zero in both the seining and trapping surveys.

INTRODUCTION

The Cosumnes River chinook salmon (*Oncorhynchus tshawytscha*) resource was surveyed from November 1998 through June 1999. Data were acquired on temporal and spatial distribution of salmon spawning and on juvenile rearing and emigration. Physical data were also collected to characterize spawning and rearing habitat conditions. The primary purpose of these surveys was to identify the relationships between the various salmon life stages and existing habitat conditions and eventually identify potential management actions that could help restore the Cosumnes River salmon population to near historic levels.

The Cosumnes River has historically supported a moderately sized fall-run chinook salmon population (Taylor 1974, Reavis 1981, Kano 1998). Between 1953 and 1973, the estimated spawner escapement to the Cosumnes River exceeded 1,000 salmon on several occasions, and exceeded 4,000 salmon twice. Since the mid-1970's, however, estimated escapement reached 1,000 fish only once and was generally 200 fish or less. In recent years, chinook salmon reared at Nimbus Hatchery on the American River have been planted into the Cosumnes River. Over 225,000 chinook salmon fry were planted into the Cosumnes River during 1996. These fish could have contributed to the 1998 fall spawner population.

The decline in the salmon population has apparently been due to substantial flow reductions during critical salmon migration periods and a shortage of suitable spawning and rearing habitat. Even though the Cosumnes River is the only river system in the Central Valley that has not been substantially altered by large-scale water development, several small dams[1] and numerous riparian diversions routinely reduce or eliminate surface flows in the lower river from spring through early winter. Low flow during this period has severely restricted and even eliminated chinook salmon immigration and emigration. Similarly, an abundance of fine sediment has apparently increased within the historic anadromous reach, reducing spawning and rearing habitat availability and possibly affecting the timing and abundance of surface flow. The 1998–1999 surveys were intended to establish a basis for addressing these issues.

METHODS

The Cosumnes River enters the Mokelumne River just upstream from the central Sacramento-San Joaquin Delta. The Cosumnes River is typically a rain-fed stream versus snow fed, originating at relatively low elevations on the western slope of the Sierra Nevada. Most of the river is unavailable to anadromous fish (Figure 1). A series of steep cascades located at Latrobe Falls, near river mile (RM) 40, is a total barrier to anadromous fish migration. The reach

[1] Jenkinson Reservoir impounded by Sly Park Dam on Sly Park Creek in the upper portion of the Cosumnes River watershed is the only notable water storage facility in the basin. Its watershed comprises less than 4% of the total Cosumnes River drainage.

generally used for salmon spawning and rearing is located between Meiss Road (RM 26) and Latrobe Falls. Generally, this reach constituted the survey area for 1998-1999.

Temperature data were collected using an electronic, recording thermograph located near Michigan Bar Road (RM 36). Flow data were obtained from records for a gaging station located at Michigan Bar that is operated by the U.S. Geological Survey and the California Department of Water Resources.

Chinook Salmon Spawning Survey

A fall-run chinook salmon spawner escapement survey was conducted on the Cosumnes River between Michigan Bar and Meiss Road Bridge[2] (Figure 1). Surveys were conducted every other week beginning on 12 November 1998 and ending 23 December 1998. The objectives of our survey were to determine: i) the number of salmon spawners; ii) spatial and temporal spawning distribution; and iii) length frequency, sex composition, and spawning success (egg retention). Aerial photos were also taken on 18 November 1998 to identify spawning distribution. The numbers of redds and live fish observed during each survey trip were also recorded and, in combination with the aerial photos, will be used to map redds, and, thus, the distribution of spawning habitat used.

A carcass mark-and-recapture survey was used to estimate spawner abundance. The stream reach between the Michigan Bar Bridge and Meiss Road Bridge was divided into two sections: 1) Michigan Bar to Highway 16 Bridge, and 2) Highway 16 Bridge to Meiss Road Bridge. The upstream section was surveyed on foot by Department of Fish and Game (DFG) personnel; the downstream section was surveyed from a canoe by Fishery Foundation staff.

Carcasses were collected and checked for completeness (i.e., with the head intact) and previously attached tags. Complete, untagged carcasses were usually tagged by attaching a colored ribbon (to indicate week tagged) to the jaw using a hog ring. Carcasses that were not tagged were chopped in half. Chopped carcasses included those: i) previously tagged, ii) on shore in a "leathery condition"; and, iii) in the downstream portion of Section 2 that would likely wash out of the survey area and never be recovered. Tagged carcasses were released into running water for recapture.

Data collected to estimate population size included the number of tagged, chopped, and recovered carcasses. All carcasses were examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or gills were pink. Data collected from primarily fresh carcasses included gender, fork length (FL) in centimeters, section of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining, as partially spent if a substantial amount of the

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[2] This reach was annually surveyed by the DFG from 1953 until 1989.

eggs remained, and unspent if the ovaries appeared nearly full of eggs. Carcasses were also examined for adipose-fin clips indicating presence of a coded-wire tag.

During data analysis, salmon ≥72 cm FL were classified as adults (>2 years old), while those <72 cm FL were classified as grilse (2 year olds). The break at 72 cm FL was based upon size distribution of carcasses measured during this survey (Figure 3).

Escapement was estimated using the Petersen formula (3.7) as described by Ricker (1975):

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

Where, N = estimated spawning population,
M = number of carcasses marked during the survey,
C = total number of carcasses examined during the survey, and
R = number of marked carcasses recovered during the survey.

Salmon Rearing Habitat Surveys

Salmon rearing habitat was surveyed from 23 March 1999 to 14 June 1999. The rearing habitat evaluation was intended to determine the temporal and spatial distributions of the various juvenile life stages occurring in the Cosumnes River. Sampling was conducted at approximately one-month intervals. The sampling sites were located near the mouth of Indian Creek (about 2.5 miles upstream of Michigan Bar), near Michigan Bar bridge, on Rancho Murieta property up and downstream of the Highway 16 Bridge, and at the Meiss Road Bridge.

Sampling was conducted using either a 25 x 4-ft or a 50 x 4-ft beach seine, depending upon sampling conditions. The larger seine was used about 1/3 of the time, typically where the stream was wide and a large seine could be easily maneuvered. Sites sampled with the large seine included those near Michigan Bar and near the Rancho Murieta airport. The smaller seine was typically used where the stream was narrow and the current was swift. Data recorded from each seine haul included the number of salmon caught, size of up to 50 salmon per haul (i.e. fork length [FL] to the nearest 0.5 mm and weight to the nearest 0.2 g) and the general habitat attributes of the site seined (e.g., area, depth, current velocity, water temperature).

Emigration Survey

The purpose of our monitoring was to determine the timing and relative abundance of juvenile fall-run salmon emigration. Timing and abundance will be compared with precedent conditions of spawning and rearing in the upper natal stream to identify relationships between manageable habitat conditions (e.g., flow, habitat availability) and salmon survival to emigration.

Emigrating juvenile salmonids were monitored at the Folsom South Canal crossing (Figure 1) using a 5-ft diameter rotary screw trap (RST). Sampling occurred from 7 April 1999 through 14 June 1999. The trap was generally serviced two to four times per week. Data recorded during each servicing included number of hours fished since the last service and the number and sizes of collected salmon. Fish were removed from the trap, sorted, and counted. All salmon were measured and weighed (FL in mm and weight in g).

RESULTS and DISCUSSION

General Results

Mean weekly flow, measured at Michigan Bar[3], during the 1998–1999 water year ranged from 26 cubic feet per second (cfs) during September 1999 to over 5,500 cfs during week 7 (7–13 February 1999). Flow was relatively low until week 4 of 1999 (17–23 January 1999) when mean weekly flow first exceeded 1,000 cfs (Figure 2). During the spawner immigration period, flow was moderately low. Mean daily flow did not exceed 100 cfs until 8 November 1998 (119 cfs), and did not exceed 200 cfs until 24 November 1998. Flow did not substantially increase until week 49 when mean daily flow exceeded 700 cfs. Mean daily flow during the emigration period remained relatively high into June 1999 (Figure 2) reaching 200 cfs by mid-June then remaining below 100 cfs after 1 July 1999.

Mean daily temperatures measured near Michigan Bar ranged from 36°F during week 52 to over 80°F during September 1999 (Figure 2). Mean weekly temperature declined to 60°F early in October (week 42), although flow was less than 70 cfs at the time.

Chinook Salmon Spawning Survey

Flow during the spawner survey ranged from 105 cfs during the first survey week (week 46) to about 200 cf during the second and third survey (weeks 48 and 50) then declined to 138 cfs during the fourth survey week (week 52) (Table 1). Water temperature declined from around 50°F to 36°F during this survey.

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[3] During the low flow season, flows measured at Michigan Bar are higher than the flows present downstream due to diversions.

Table 1. Summary of flow, water temperature, redd counts, live salmon counts, carcass counts, and tagging results during the fall-run chinook salmon survey of the Cosumnes River, November - December 1998.

Survey period (date)	Section	Flow (cfs)	Temperature °F	Salmon carcasses		Redds	Live salmon
				Fresh adult/grilse	Decayed		
1 Week 46 (12 Nov)	1	105	50	3	2	26	35+
	2	Not surveyed					
2 Week 48 (24 Nov)	1	202	51	14	1	26	18
	2	202	51	5	12	81	56
3 Week 50 (8–9 Dec)	1	203	42	1	0	44	5
	2	201	43	10	30	132	31
4 Week 52 (23 Dec)	1	Not surveyed					
	2	138	36	4 / 1	22	-	3
All	1			18	3	96	58
	2			20	64	213	90
	Total			38	67	309	148

We observed 105 carcasses including 38 fresh carcasses (37 adults [97%], 1 grilse [3%]), and 67 that were classified as decayed or skeletons (Table 1). Thirty-three carcasses were tagged and six (18%) were later recovered. Total estimated escapement for the survey reach, using the Petersen formula, was 544 salmon (528 adults, 16 grilse). Based on aerial redd photos, over 95% of spawning occurred between Michigan Bar and Meiss Road Bridge; thus, spawner escapement to the Cosumnes River was about 572 salmon.

The spawner escapement estimate of 544 calculated from the Petersen formula is likely an overestimate based on Law's (1994) analysis. Law concluded this formula could more than double the actual population particularly when the recovery rate is low as it was in this study (18%). As such, we concluded that the actual spawner population size was more likely between 250 and 350 adult salmon.

Forty carcasses were measured and sexed. The only carcass classified as a grilse was a male measuring 60 cm FL (Figure 3). Females (n=23) ranged from 72 to 91 cm FL; males (n=17) ranged from 60 to 97 cm FL. All but one male was $\geq$ 73 cm FL. The ratio of females:males was 1.35:1. Twenty-one (91%) of the 23 females examined for egg retention had completely spawned, and two (9%) had only partially spawned.

Spawning was concentrated between the first and third surveys (12 November 1998–9 December 1998) (Figure 4). The highest numbers of redds (176, 57%) and carcasses (41, 39%) were counted during the third survey week (6–12 December 1998) (Table 1). We also counted 107 redds (35%) and 32 carcasses (30%) during the second survey week (22–28 November 1998). Redds constructed subsequent to surveys in previous weeks were not easily distinguished. As such, the number of carcasses counted is likely a more reliable indicator of temporal spawning distribution, although there was no discrepancy in this case.

Results of the aerial photographic surveys and the carcass surveys indicated that most spawning occurred between Meiss Road and Highway 16. Over 69% of the redds counted during the carcass survey and 55% of the redds counted from the aerial photographs were in this section. Sixteen redds (3%) were counted upstream of Michigan Bar on the aerial photographs.

Salmon Rearing Habitat Surveys

Flow during the rearing phase of the survey (March–June 1999) ranged from more than 1,500 cfs during week 17 to less than 100 cfs during week 27 (Figure 2). Mean weekly temperature ranged from 45°F during week 15 to 78°F during week 27 (Figure 2).

A total of 498 juvenile salmon was collected in 45 seine hauls made biweekly from 23 March 1999 through 29 June 1999 (Table 2, Figure 5). Twenty-one percent (107) were collected in 13 hauls during March, 66% (327 in 8 hauls) in April, 13% (64 in 11 hauls) in May and zero in 13 hauls during June.

Table 2. Catch statistics for chinook salmon collected by beach seine in the Cosumnes River, March–June 1999.

Date	Location	Area seined (ft^2)	Number caught (n)	n/1,000 ft^2	Mean FL in mm (range)
23 March	Ranch Murieta (RM) airport	429	1023.3	23.3	41.8(38–52)
23 March	Meiss Rd Bridge	83	0	0.0	-
23 March	Michigan Bar	1,397	1	0.7	34.0(34)
23 March	Michigan Bar	322	0	0.0	-
23 March	RM airport	N/A	15	N/A	40.7(39–49)
24 March	RM Golf Course	1,376	0	0.0	-
24 March	RM Golf Course	519	0	0.0	-
24 March	RM Golf Course	558	1	1.8	38(38.0)
24 March	RM Golf Course	N/A	0	N/A	-
24 March	RM Golf Course	N/A	0	N/A	-
24 March	RM airport	992	7	7.1	37.7(35–40)
24 March	RM	360	0	0.0	-
24 March	RM airport	995	73	73.4	43.2(37–53)
	March Totals		107		42.4(34–53)
21 April	Indian Creek	319	7	21.9	45.1(36–58)
21 April	Indian Creek	378	0	0.0	0
22 April	RM Golf Course	155	0	0.0	0
22 April	RM Golf Course	168	101	602.0	47.7(37–68)
22 April	RM airport	928	33	35.6	44.7(40–61)
22 April	RM airport	1,209	40	33.1	49.2(39–64)
23 April	Michigan Bar	1,035	2	1.9	61.5(61–62)
23 April	Michigan Bar	746	144	193.0	44.1(34–60)
	April Totals		327		46.0(34–68)

Table 2 (cont.)

Date	Location	Area seined (ft^2)	Number caught		Mean FL in mm (range)
19 May	RM Golf Course	1,541	19	12.3	61.8(55–71)
19 May	RM airport	992	10	10.0	62.4(55–77)
19 May	RM airport	1,106	5	4.5	57.0(50–62)
19 May	RM airport	1,838	6	3.3	62.8(57–77)
20 May	Michigan Bar	1,406	1	0.7	59.0(59)
20 May	Michigan Bar	294	8	27.2	68.1(61–74)
20 May	Michigan Bar	412	2	4.9	65.5(62–69)
20 May	Michigan Bar	595	0	0.0	-
20 May	Indian Creek	314	2	6.4	61.0(61)
20 May	Indian Creek	412	11	26.7	57.6(48–67)
20 May	Indian Creek	776	0	0.0	-
	May Totals		64		61.7(48–77)
4 June	-	957	0	0.0	-
4 June	-	744	0	0.0	-
8 June	RM airport	760	0	0.0	-
8 June	RM airport	768	0	0.0	-
8 June	RM airport	1,022	0	0.0	-
8 June	RM Golf Course	382	0	0.0	-
8 June	RM Golf Course	481	0	0.0	-
29 June	Indian Creek	450	0	0.0	-
29 June	Indian Creek	164	0	0.0	-
29 June	Indian Creek	145	0	0.0	-
29 June	Michigan Bar	585	0	0.0	-
29 June	Michigan Bar	392	0	0.0	-
29 June	Michigan Bar	470	0	0.0	-
	June Totals		0	0.0	
	Season Totals		498		34–77

Juvenile salmon densities ranged from 0.0 fish/ft^2 to over 600 fish/ft^2 (Table 2). The highest densities were hear Rancho Murieta early (March and April) and in the upper reach later (May).

Salmon sizes ranged from 34–53 mm FL (mean = 42.4 mm FL) in March, from 34–68 mm FL (mean = 46.0 mm FL) in April, and from 48–77 mm FL (mean = 61.7 m FL) in May (Figures 6 and 7). Recently emerged-sized salmon (<45 mm FL) were last captured during the April 23 seining survey.

Emigration Surveys

The mean weekly flow during this survey increased from 1,048 cfs in week 15 (4–10 April 1999) to 1,454 cfs in week 17 (18–24 April 1999), then gradually decreased to a low of 268 cfs during the last week of trapping (13–19 June 1999) (Table 3, Figure 2). Mean weekly water temperatures generally increased during this survey from 45°F during week 15 to 70° F during week 25. Temperature first exceeded 60°F during week 22.

Weekly catch/hr ranged from 0.25fish/h in weeks 15 and 17 down to 0.00 during weeks 24 and 25 (Figure 8). Given that the peak in seine survey catches occurred during April 1999, we concluded that the peak of emigration was also represented in our trapping effort (cf. Figures 5 and 8). The mean weekly size increased as the season progressed from 38.7 mm FL in week 15 to 78.1 mm FL in week 23 (Figure 9). Recently emerged-sized salmon were last caught during week 20 (9–15 May 1999) (Figures 9–12).

Table 3. Summary of rotary screw trap catches for the Cosumnes River during 4 April 1999 through 14 June 1999. The trap was located at the Folsom South Canal crossing.

Week	Dates trap were serviced	Mean weekly flow - (cfs)	Mean weekly temperature °F	Hours fished	Number salmon caught	Mean (range) FL in mm	Catch/hr
15	8, 9 April	1,048	46	44	11	38.7(33–47)	0.25
16	12, 14, 16 April	1,237	54	165	30	38.1(35–47)	0.18
17	19, 21, 23 April	1,454	55	120	30	38.3(33–48)	0.25
18	26, 30 April	1,032	54	168	21	52.8(36–90)	0.125
19	3, 5, 7 May	984	54	166	19	62.4(38–85)	0.11
20	10, 12, 14 May	816	57	168	31	63.8(39–75)	0.18
21	17, 19 & 21 May	649	59	170	14	67.9(56–82)	0.08
22	24, 26 May	716	64	121	11	70.0(62–82)	0.09
23	30 May, 1, 3, 4 June	511	62	166	11	78.1(72–86)	0.06
24	7 June	358	66	73	0	-	0.00
25	14 June	268	70	168	0	-	0.00
Totals				1,530	178	33–90	0.12

CONCLUSIONS

Salmon life history activity in the Cosumnes River appeared strongly linked to flow and temperature during the 1998-1999 surveys (Figures 13 and 14). Temperature declined below 60°F early in October, when flow was well below 100 cfs at Michigan Bar. However, spawning did not begin until late November, after flows at Michigan Bar, and possibly downstream, had increased to above 200 cfs. Apparently low flows delayed upstream salmon migration and spawning, relative to our knowledge of chinook salmon spawning elsewhere in the Central Valley.

The spawning period was relatively short occurring while flows were well below the eventual high levels brought on by storms during mid-January. Emergence occurred up to at least 27 weeks after spawning started, 25 weeks after peak spawning, ending in mid-May as flow declined and temperatures approached 60°F (Figures 13 and 14). The numbers of salmon caught by RST and seine correspondingly decreased as temperature increased and flow decreased. Salmon catches reached zero in early June when temperatures reached above 65°F. Apparently rising temperatures forced juvenile salmon to leave the natal stream reaches.

Estimated escapement was relatively high compared to the post 1970 estimates (Figure 15). As discussed above, escapement estimates made since the mid-1970s were typically less than 200 compared to the 1998–1999 estimate of nearly 600 salmon.

ACKNOWLEDGMENTS

The Cosumnes River surveys were supported by funding from the US Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program pursuant to the Central Valley Project Improvement Act intended to improve anadromous fish habitat in California's Central Valley streams. Trevor Kennedy and Keith Whitener collected carcass survey data under contract with the Fishery Foundation. Survey data were gathered by Anthony Ciarico, Robert Coyan, William Guthrie and Ray Von Flu, all with the DFG. Katherine Berry, Olivia Willis and Katy Janssen with the DFG assisted in preparing the graphics.

LITERATURE CITED

Law, P. M. W. 1994. A simulation study of salmon carcass survey by capture-recapture method. Calif.Fish & Game. 80(1):14-28.

Kano, R .M. (ed.). 1998. Annual Report. Chinook salmon spawner stocks in California's Central Valley, 1989. Inland Fish. Div. Admin. Rept. 98-2.

Reavis, R. L . Jr. (ed.). 1981. Chinook (King) salmon spawning stocks in California's Central Valley, 1979. Inland Fish. Div. Admin. Rept. 81-4.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dept. of Environ., Fish. and Mar. Serv. Bull. 191. 382 pp.

Taylor, S. N. (ed.). 1974. Chinook (King) salmon spawning stocks in California's Central Valley, 1972. Inland Fish. Div. Admin. Rept. 74-6.

FIGURES

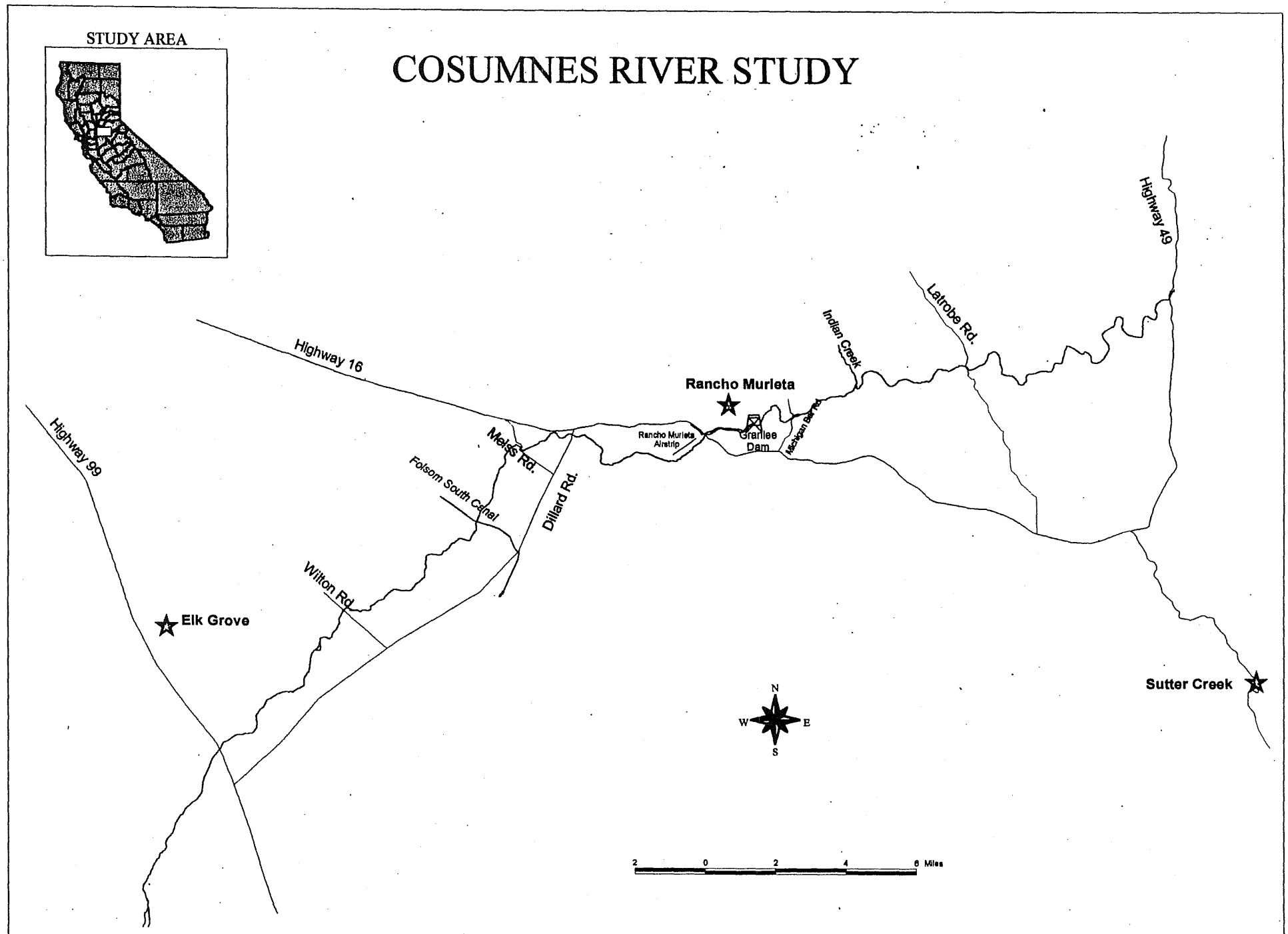

Figure 1. Location of Cosumnes River study landmarks.

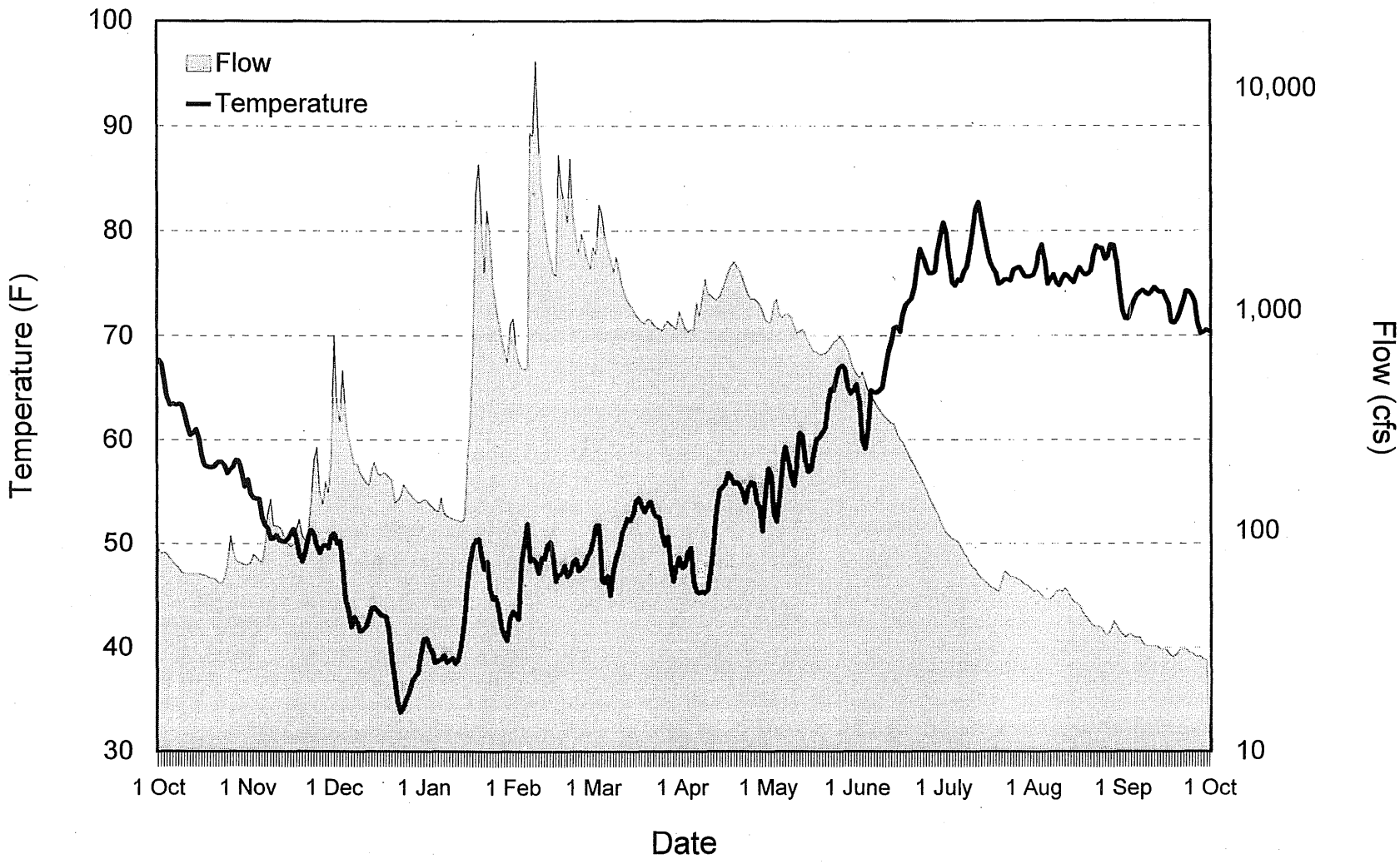

Figure 2. Mean daily flow (cfs) and temperature (F) measured near Michigan Bar (RM 36) on the Cosumnes River, October 1998 - September 1999.

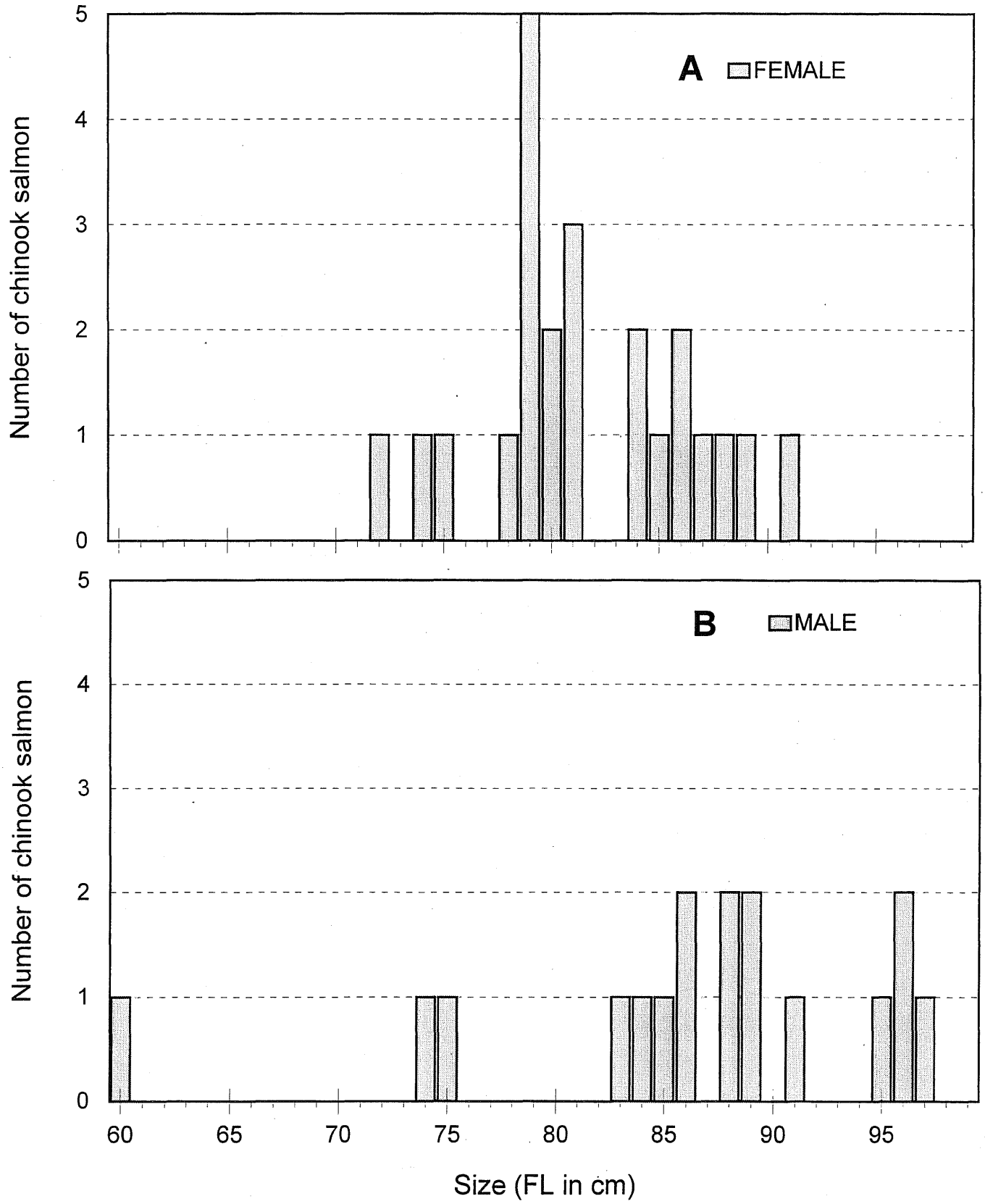

Figure 3. Length-frequency distributions for (A) female and (B) male salmon measured during the Cosumnes River fall-run chinook salmon escapement survey, November - December 1998.

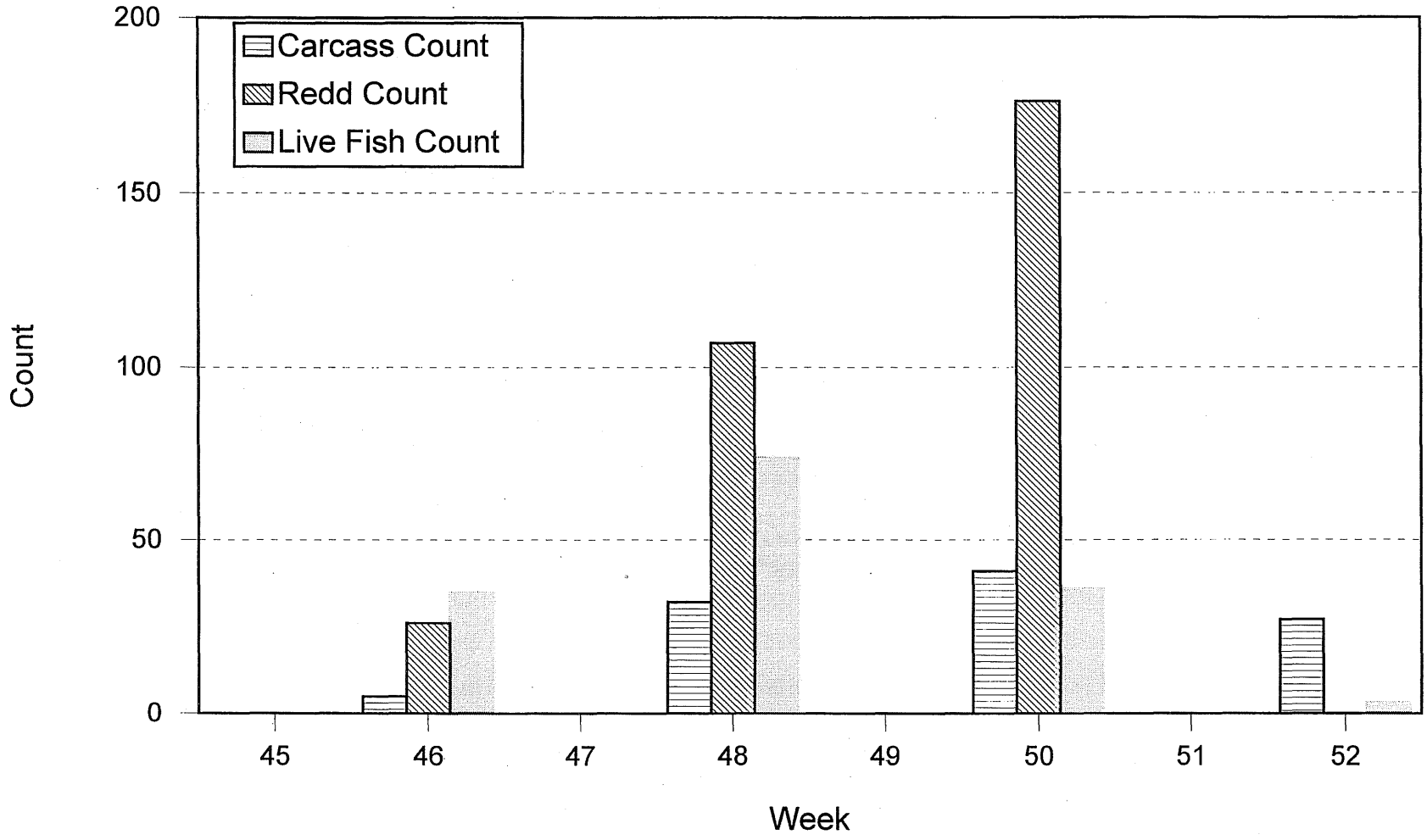

Figure 4. Temporal distribution of carcass counts (fresh and decayed), redd counts and counts of live salmon made on the Cosumnes River, 12 November - 23 December 1998.

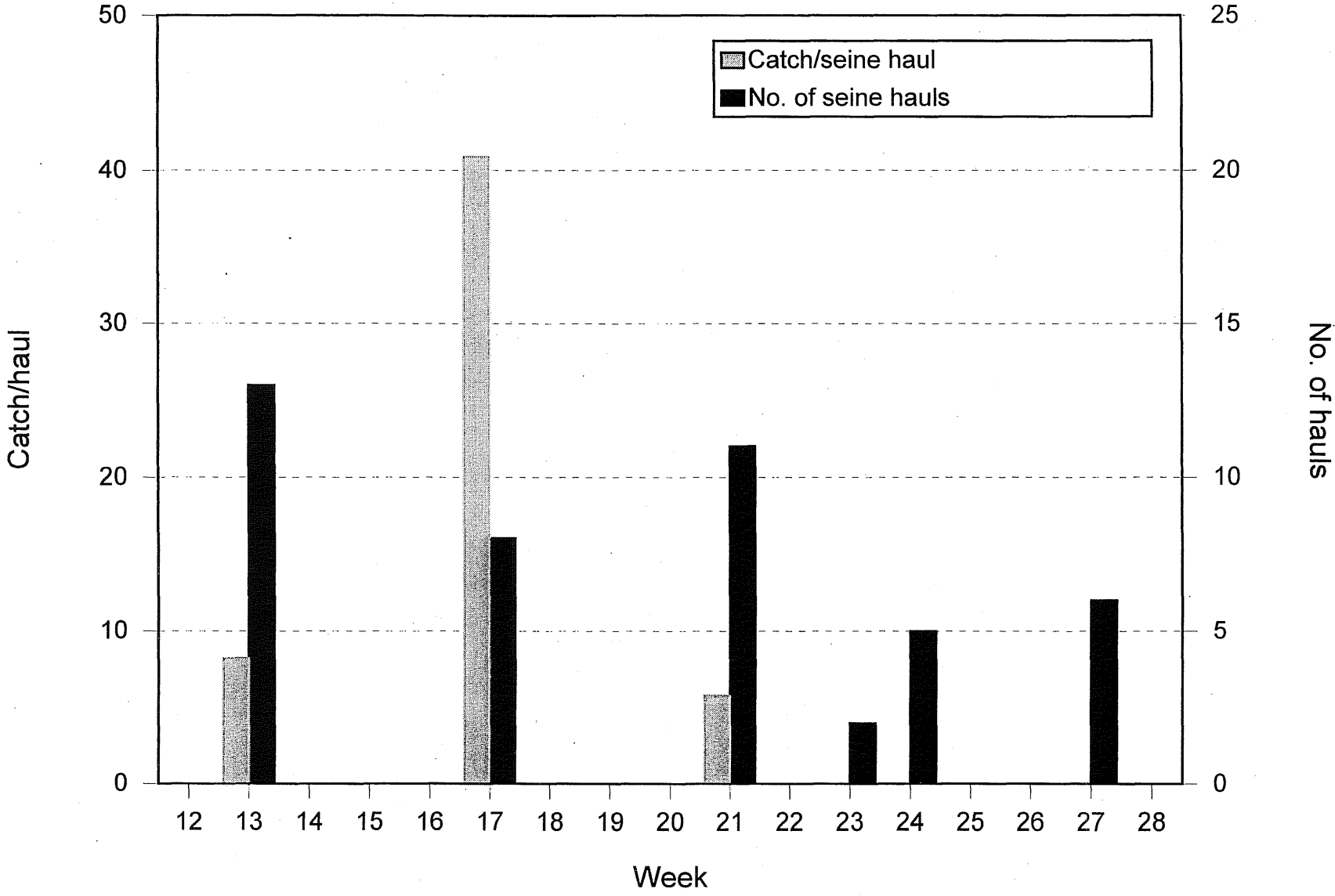

Figure 5. Temporal distribution of seining effort and catch made during the salmon rearing survey on the Cosumnes River, 23 March - 29 June 1999.

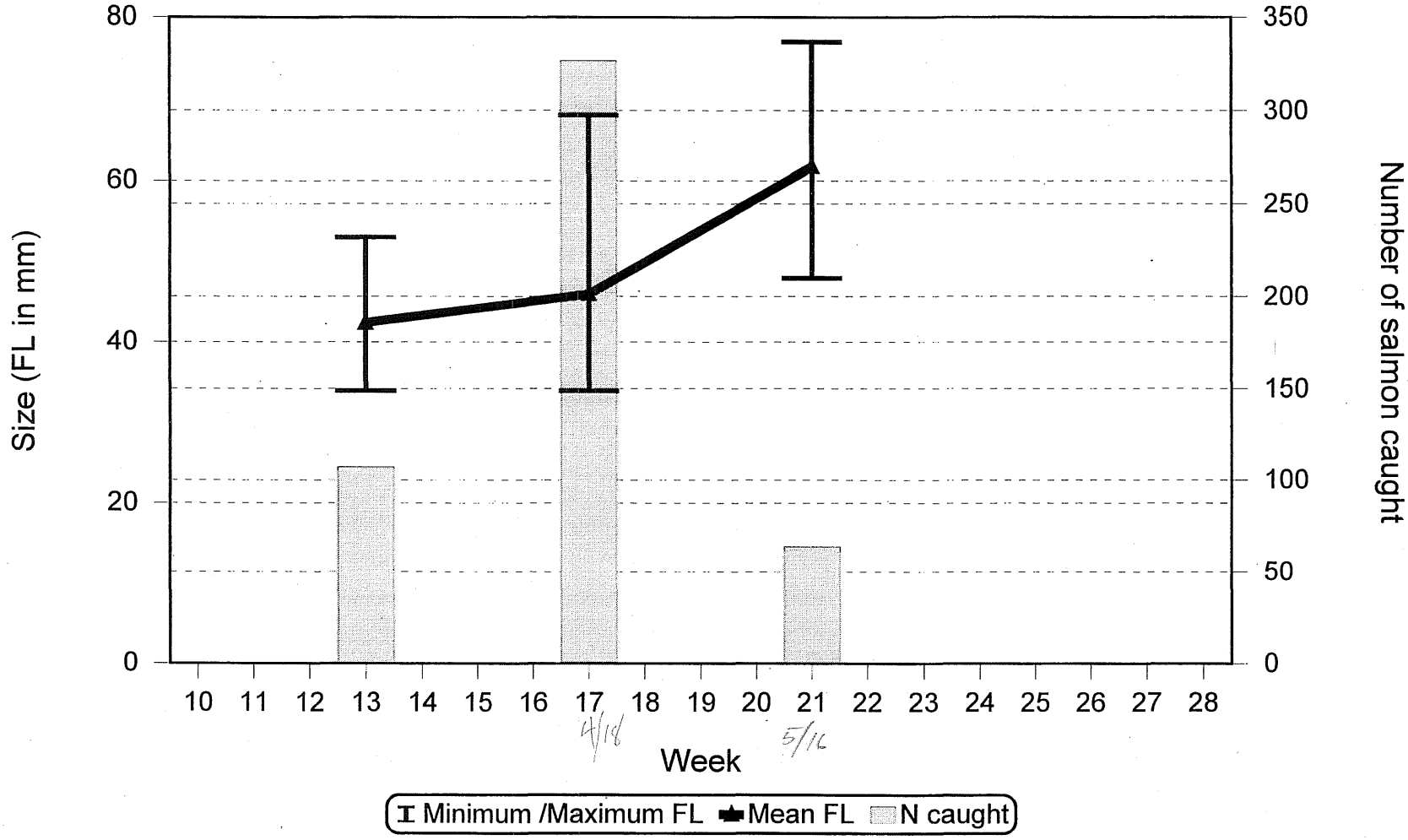

Figure 6. Temporal distribution of size (FL) and number of salmon caught by seine during the salmon rearing survey on the Cosumnes River, 23 March - 29 June 1999.

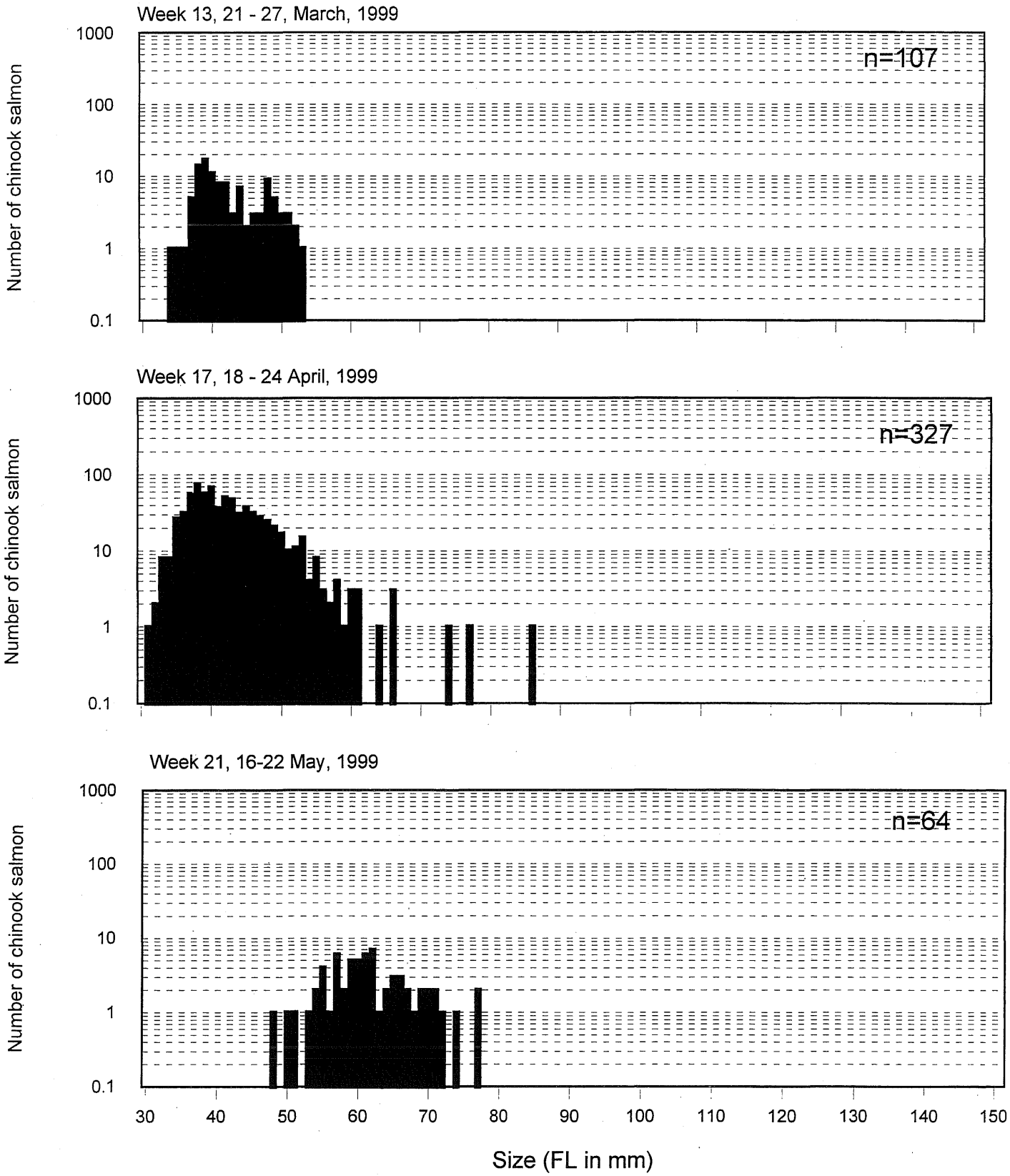

Figure 7. Size distribution of chinook salmon collected by beach seine in the Cosumnes River, 21 March - 22 May 1999.

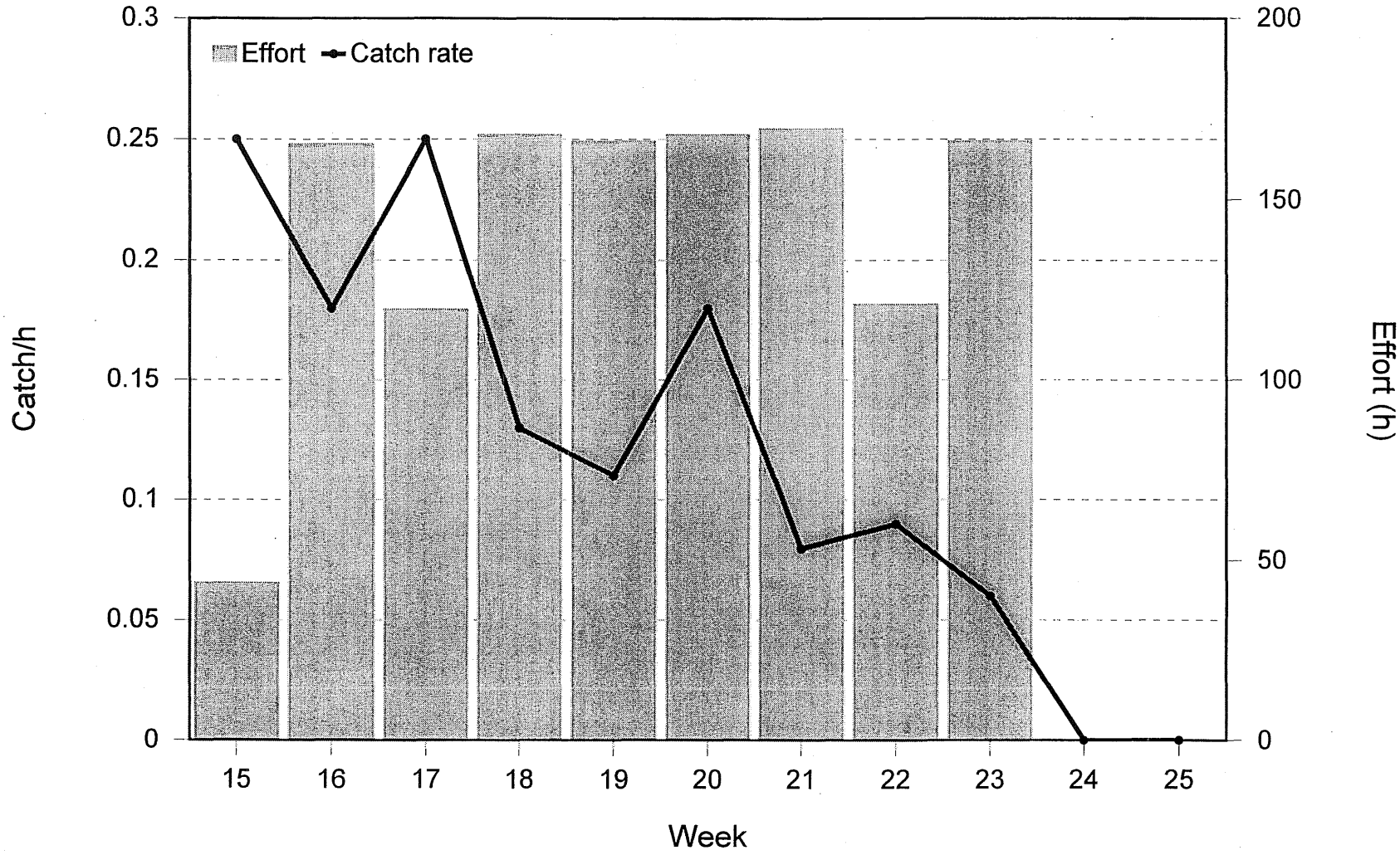

Figure 8. Weekly catch rate (n/h) of chinook salmon and hours fished by rotary screw trap on the Cosumnes River, April 1999 - June 1999.

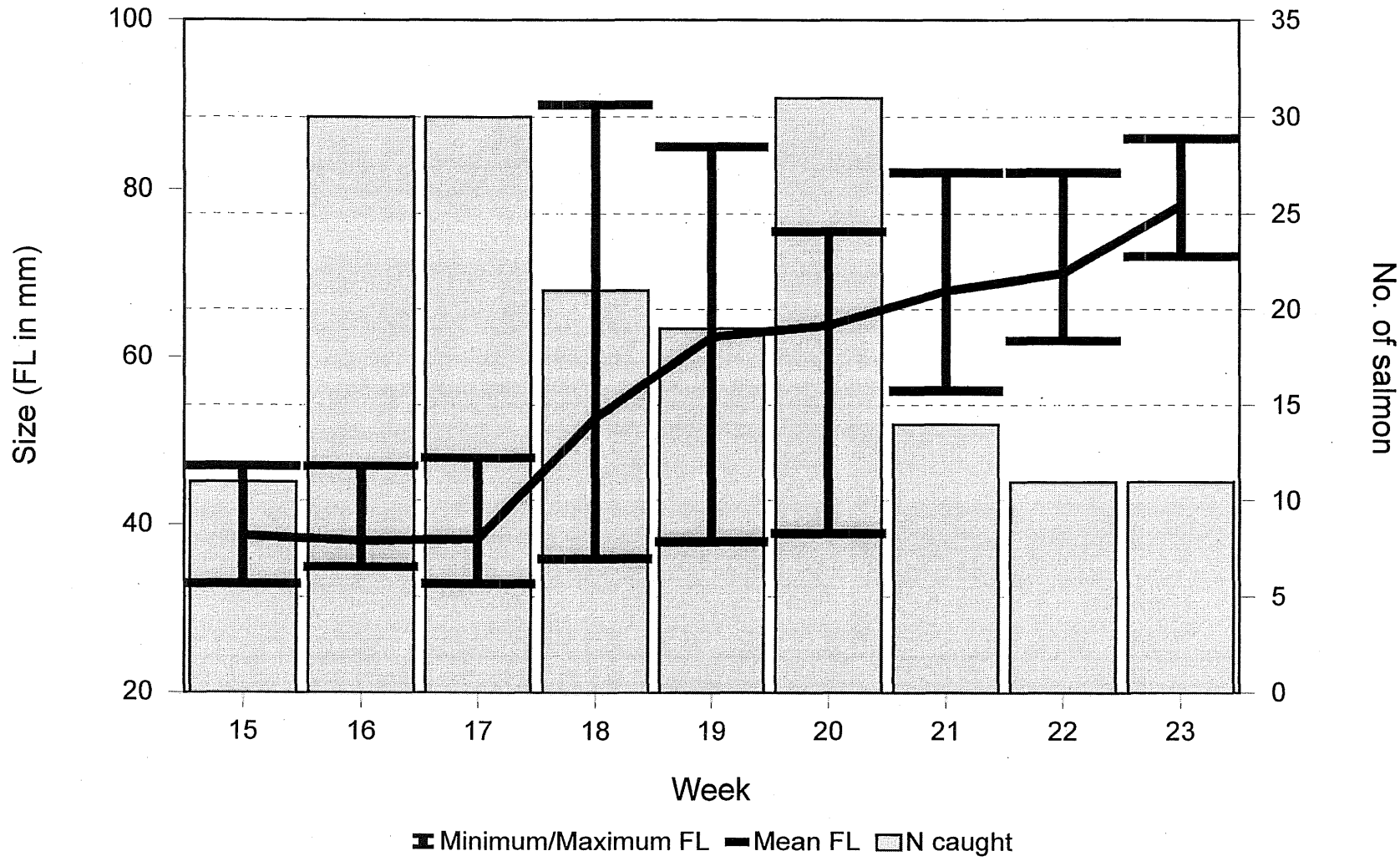

Figure 9. Weekly catch and size statistics of chinook salmon caught by rotary screw trap on the Cosumnes River, April 1999 - June1999.

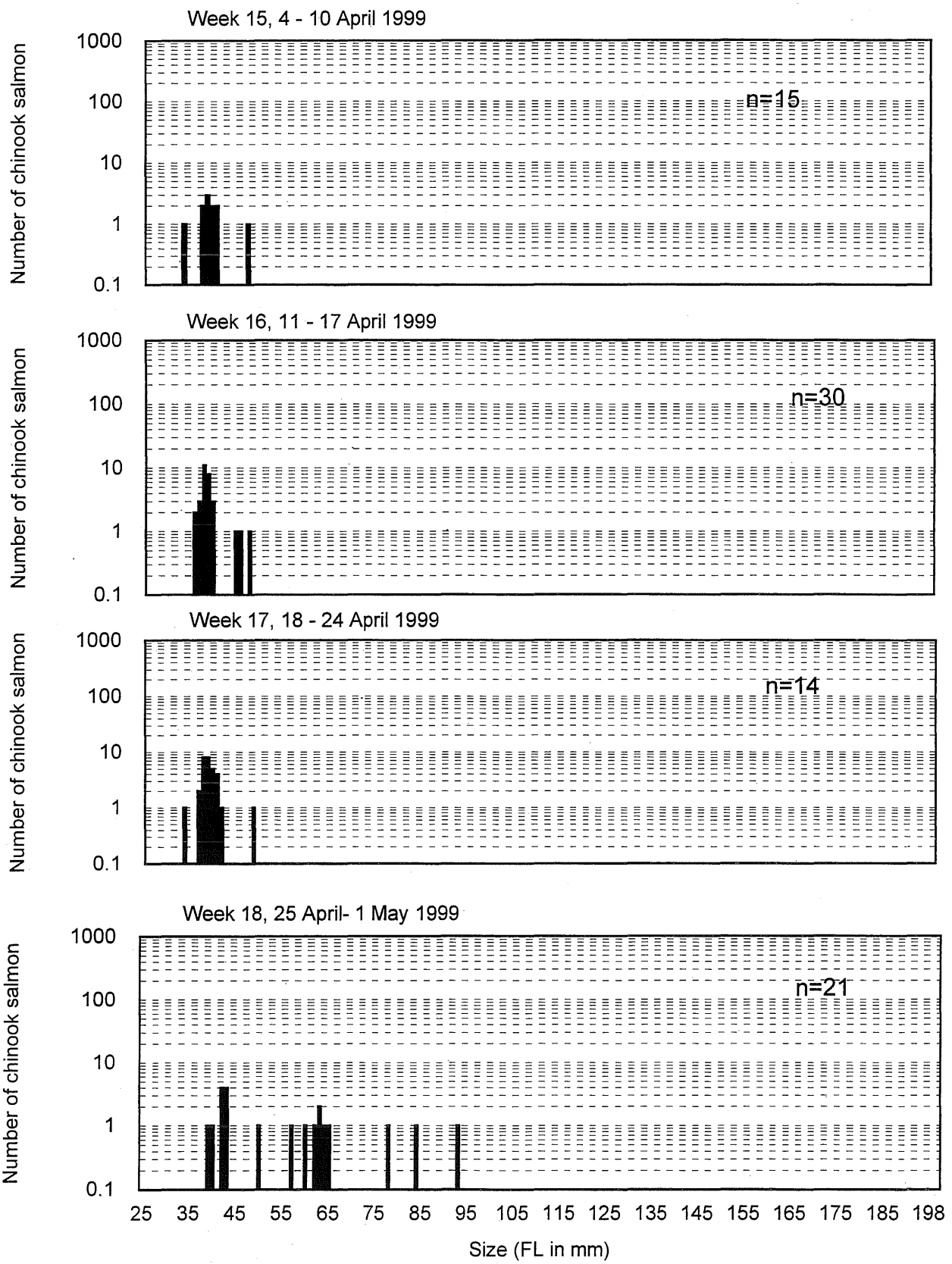

Fig 10. Size distribution of chinook salmon caught by rotary screw trap in the Cosumnes River, 4 April - 1 May 1999.

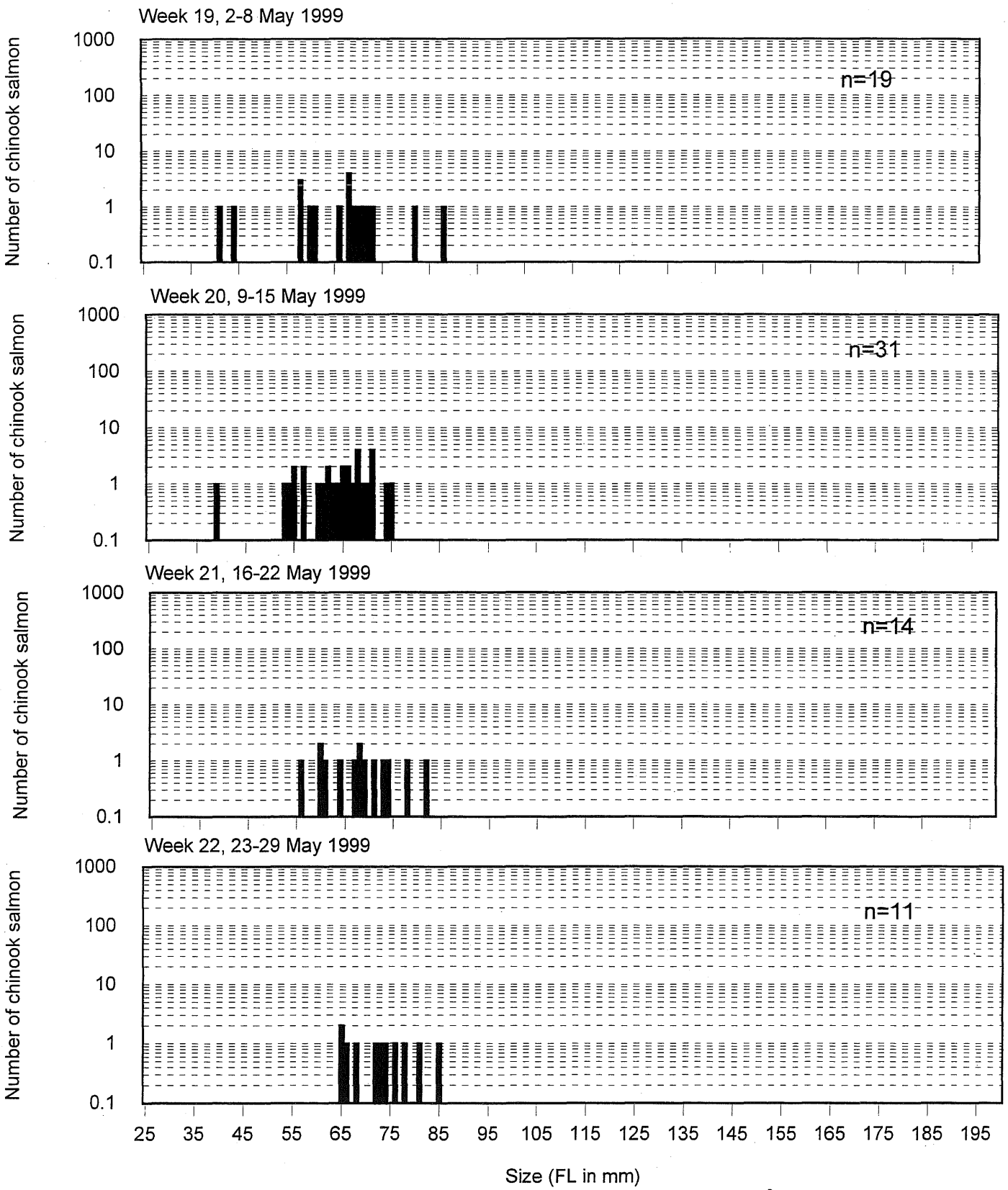

Figure 11. Size distribution of chinook salmon collected by rotary screw trap in the Cosumnes River, 2 May - 29 May 1999.

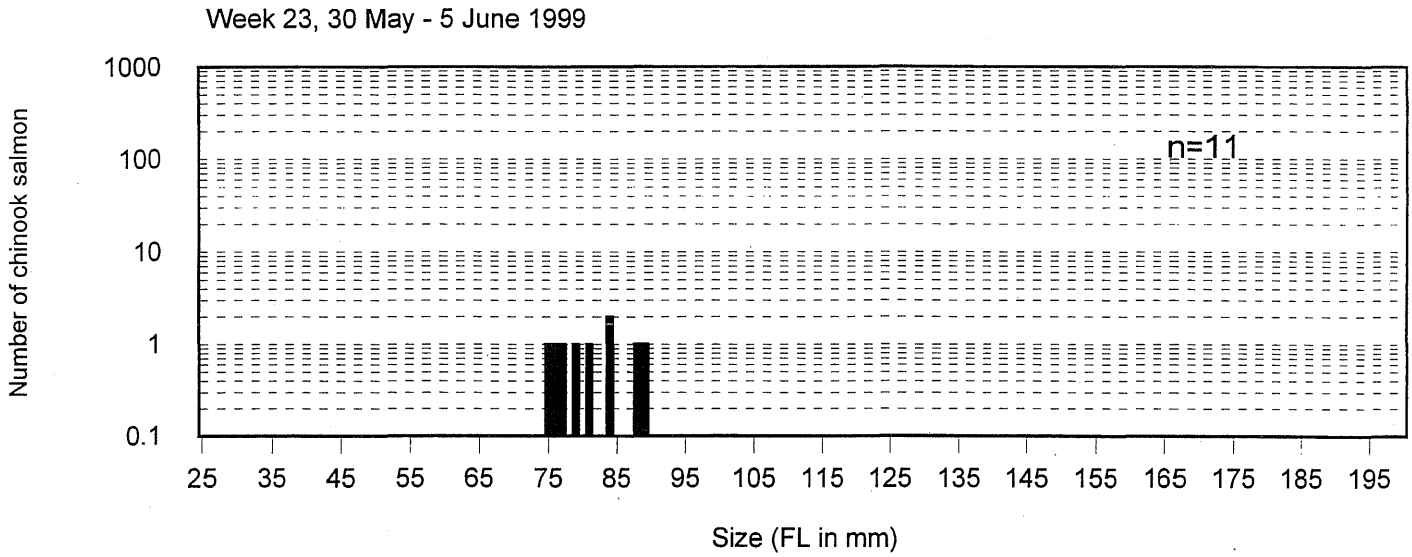

Figure 12. Size distribution of chinook salmon collected by rotary screw trap in the Cosumnes River, 30 May - 5 June 1999.

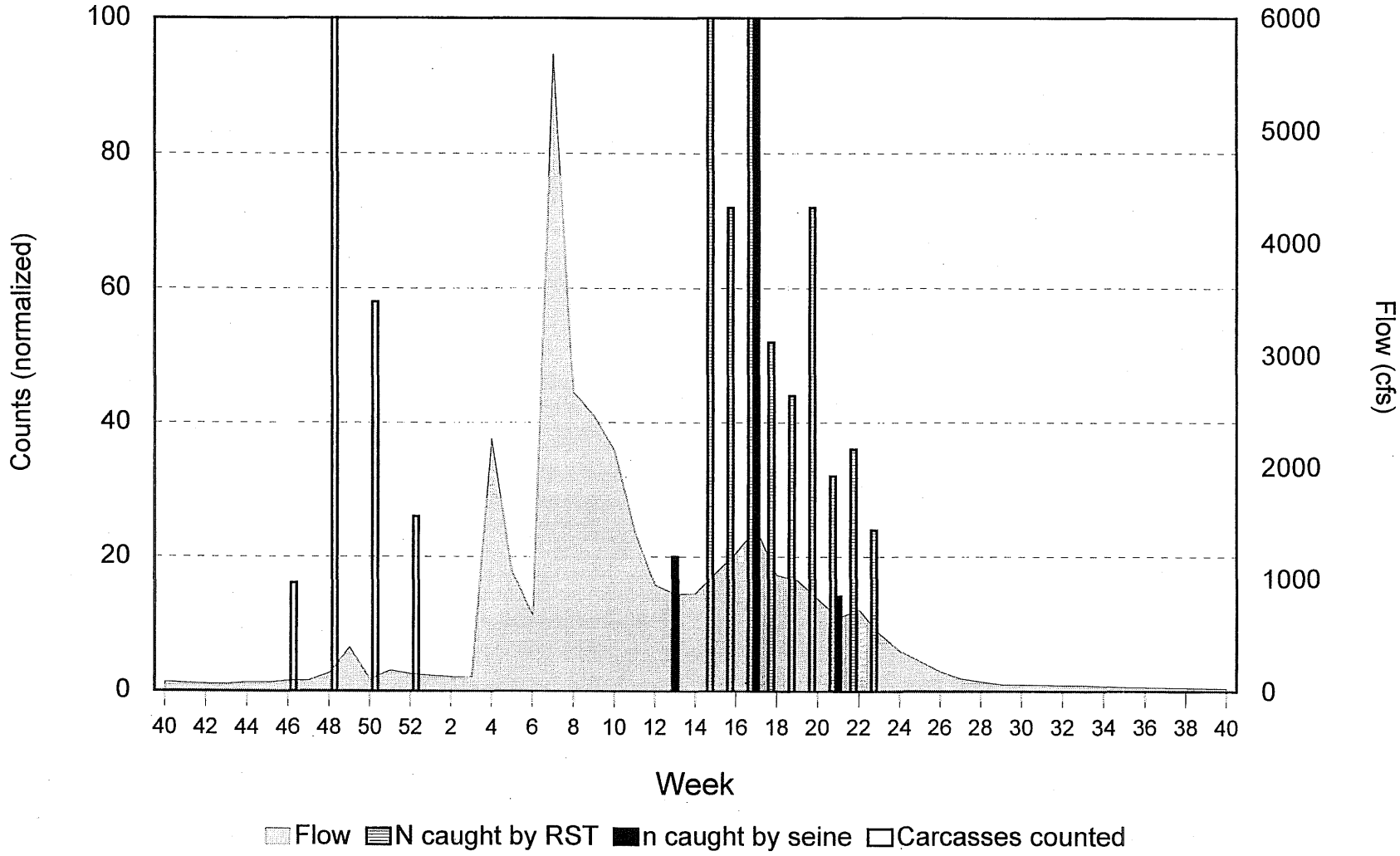

Figure 13. Temporal distribution of carcass counts, seine and rotary screw trap catches relative to flow on the Cosumnes River, October 1998 - September 1999.

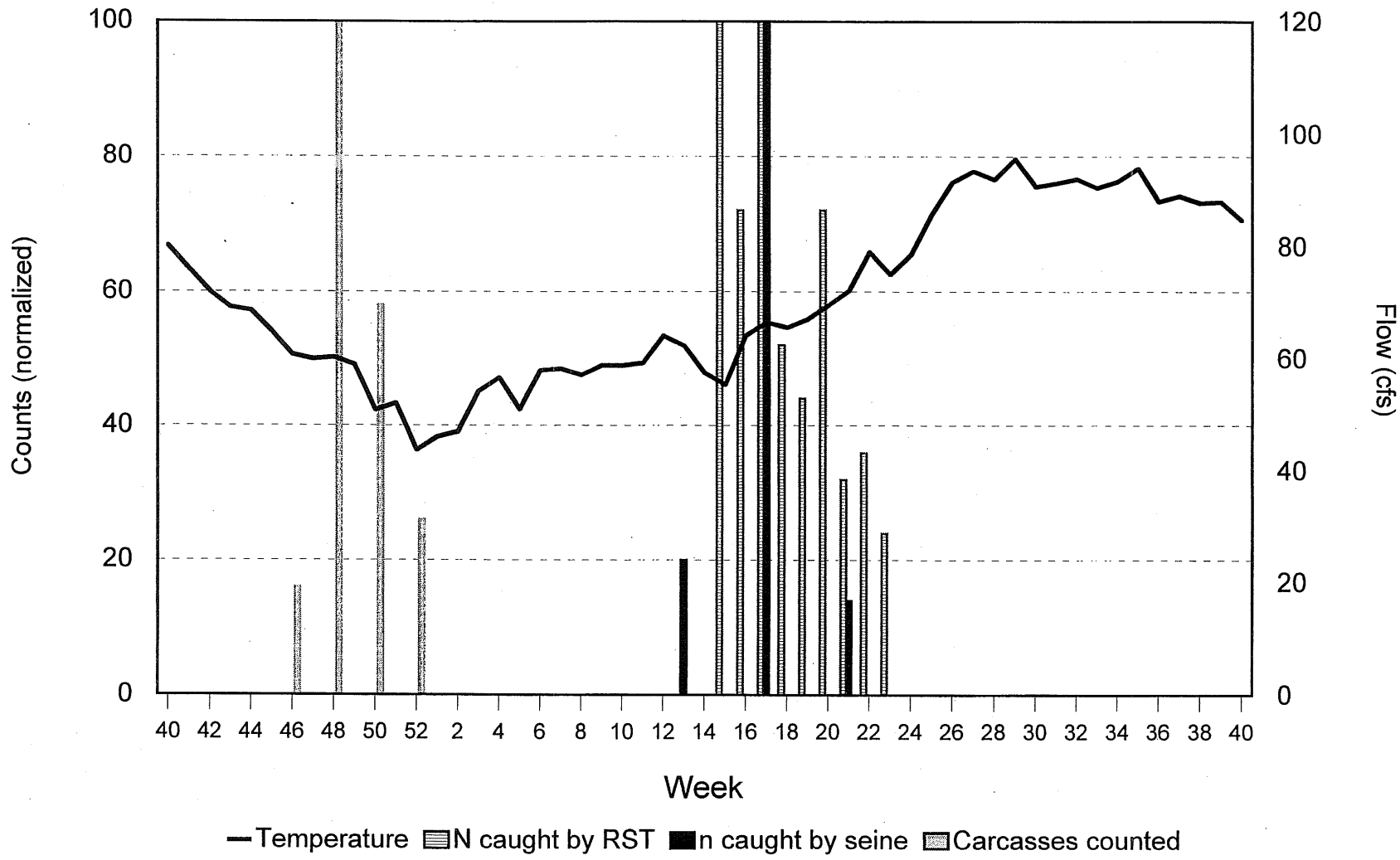

Figure 14. Temporal distribution of carcass counts, seine and rotary screw trap catches relative to temperature on the Cosumnes River, October 1998 - September 1999.

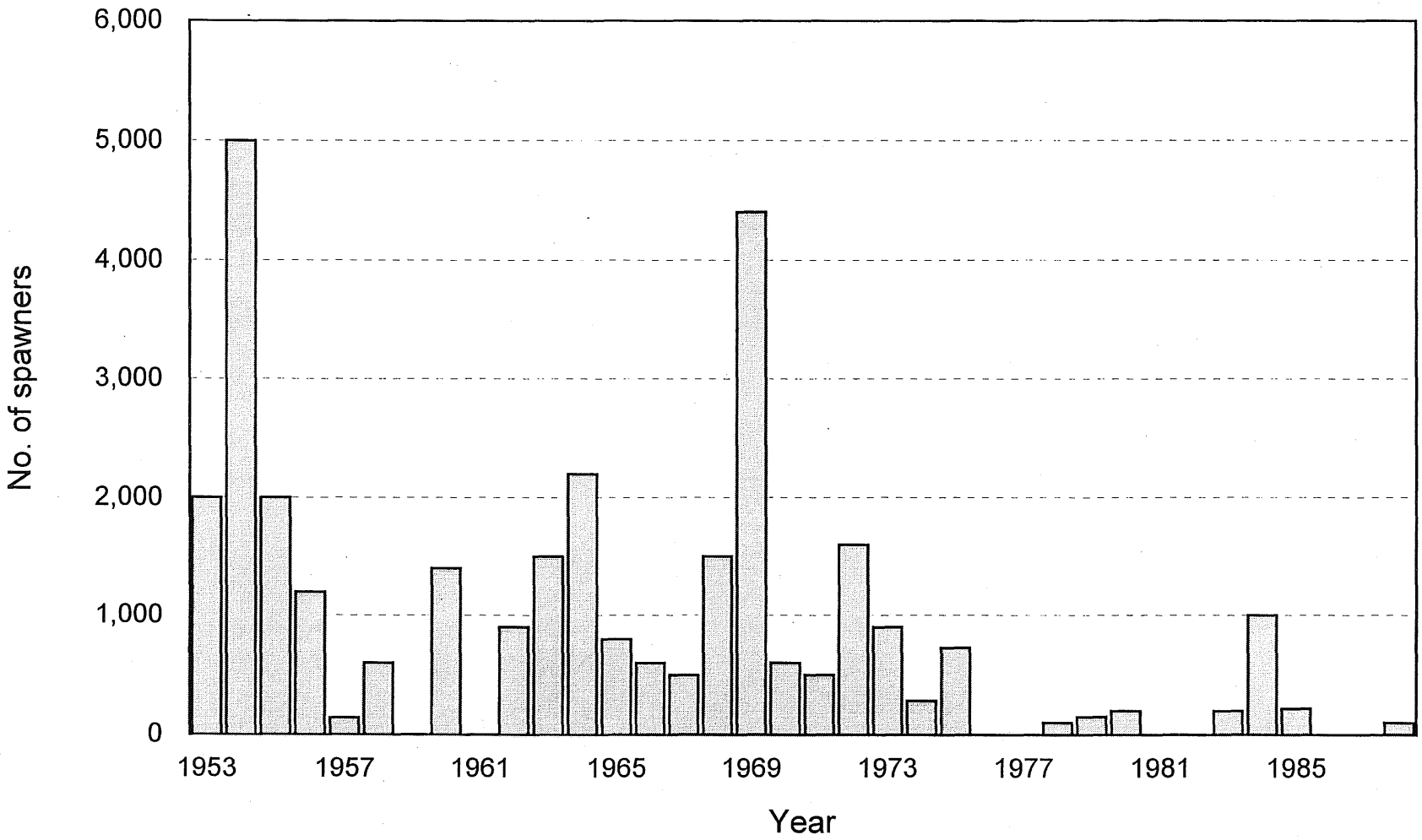

Figure 15. Estimated annual chinook salmon escapement to the Cosumnes River, 1953–1988. (No estimates were made during 1959, 1961, 1976, 1977, 1981, 1982, and 1986).